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Butler

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(54) **WIRELESS ACCESS NODE FAULT RECOVERY USING INTEGRATED ACCESS AND BACKHAUL**

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(51) **Int. Cl.**

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H04W 36/00	(2009.01)
H04W 24/04	(2009.01)
H04W 8/30	(2009.01)
H04W 36/06	(2009.01)

(52) **U.S. Cl.**
CPC ***H04W 36/305*** (2018.08); ***H04W 8/30*** (2013.01); ***H04W 24/04*** (2013.01); ***H04W 36/0022*** (2013.01); ***H04W 36/0033*** (2013.01); ***H04W 36/06*** (2013.01)

(58) **Field of Classification Search**
USPC 455/436, 445
See application file for complete search history.

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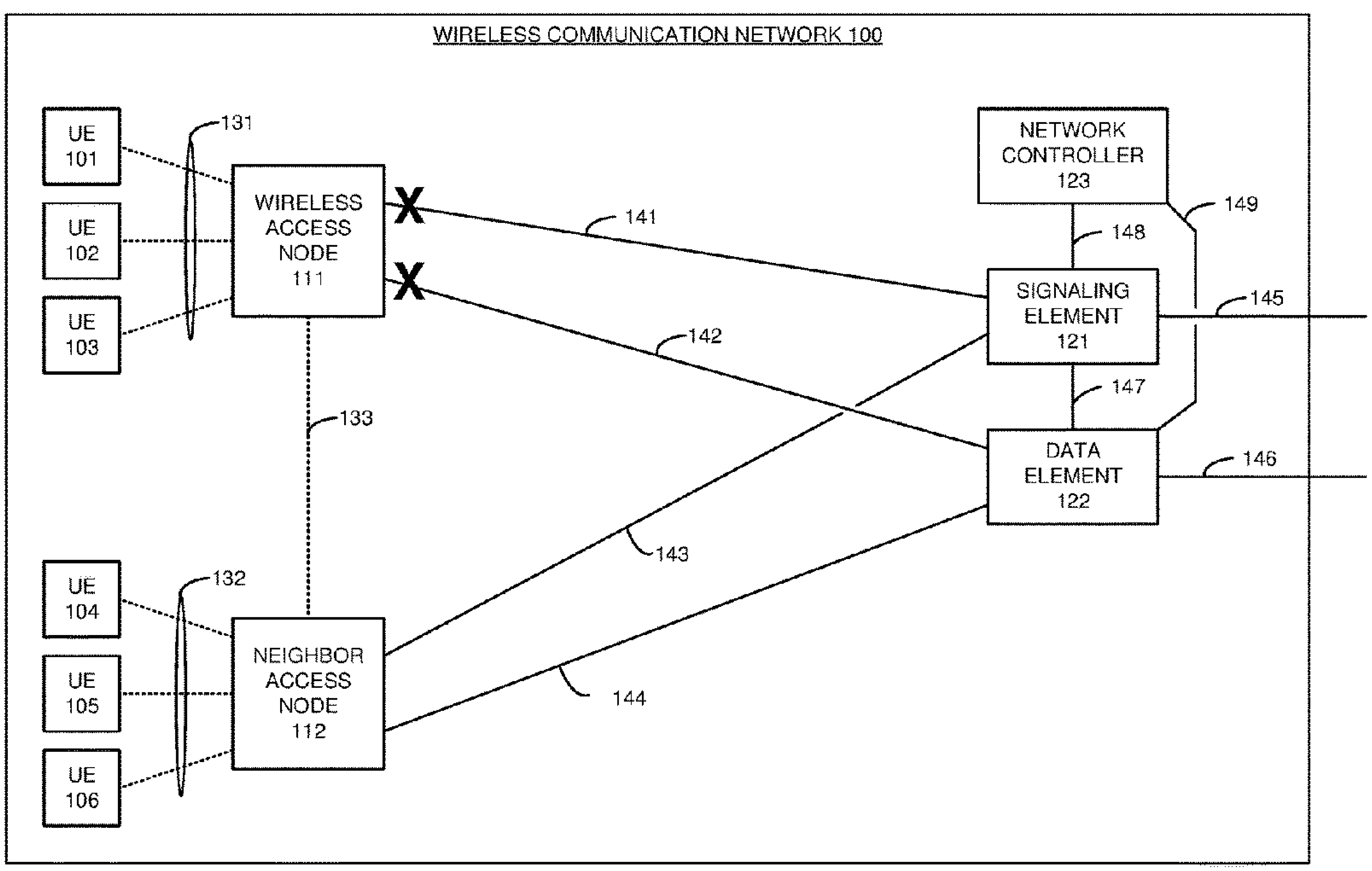
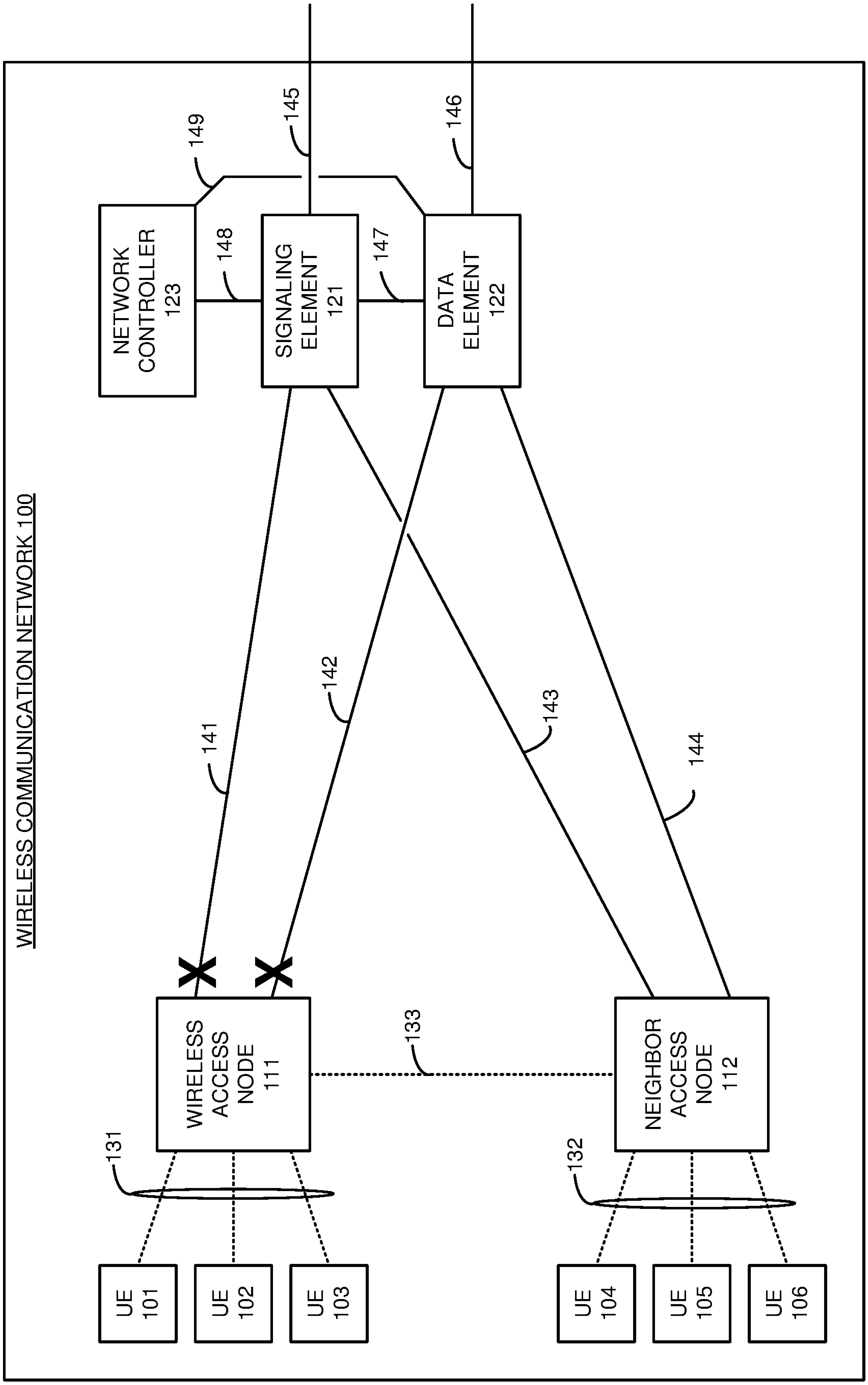
Primary Examiner — David Q Nguyen

(57) **ABSTRACT**

In a wireless access node, a baseband unit (BBU) detects a fault and responsively directs an Integrated Access and Backhaul (IAB) Mobile Terminal (MT) to scan for a wireless IAB service. The IAB MT scans for the wireless IAB service and establishes a wireless IAB link. The BBU exchanges fault data with the IAB MT. The IAB MT wirelessly exchanges the fault data with a neighbor access node over the wireless IAB link. The BBU recovers from the fault in response to the fault data.

20 Claims, 9 Drawing Sheets

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NETWORK CONTROLLER 123
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DATA ELEMENT 122
149
145
146
148
147
141
142
143
144
WIRELESS ACCESS NODE 111
NEIGHBOR ACCESS NODE 112
133
131
132
UE 101
UE 102
UE 103
UE 104
UE 105
UE 106

FIGURE 1

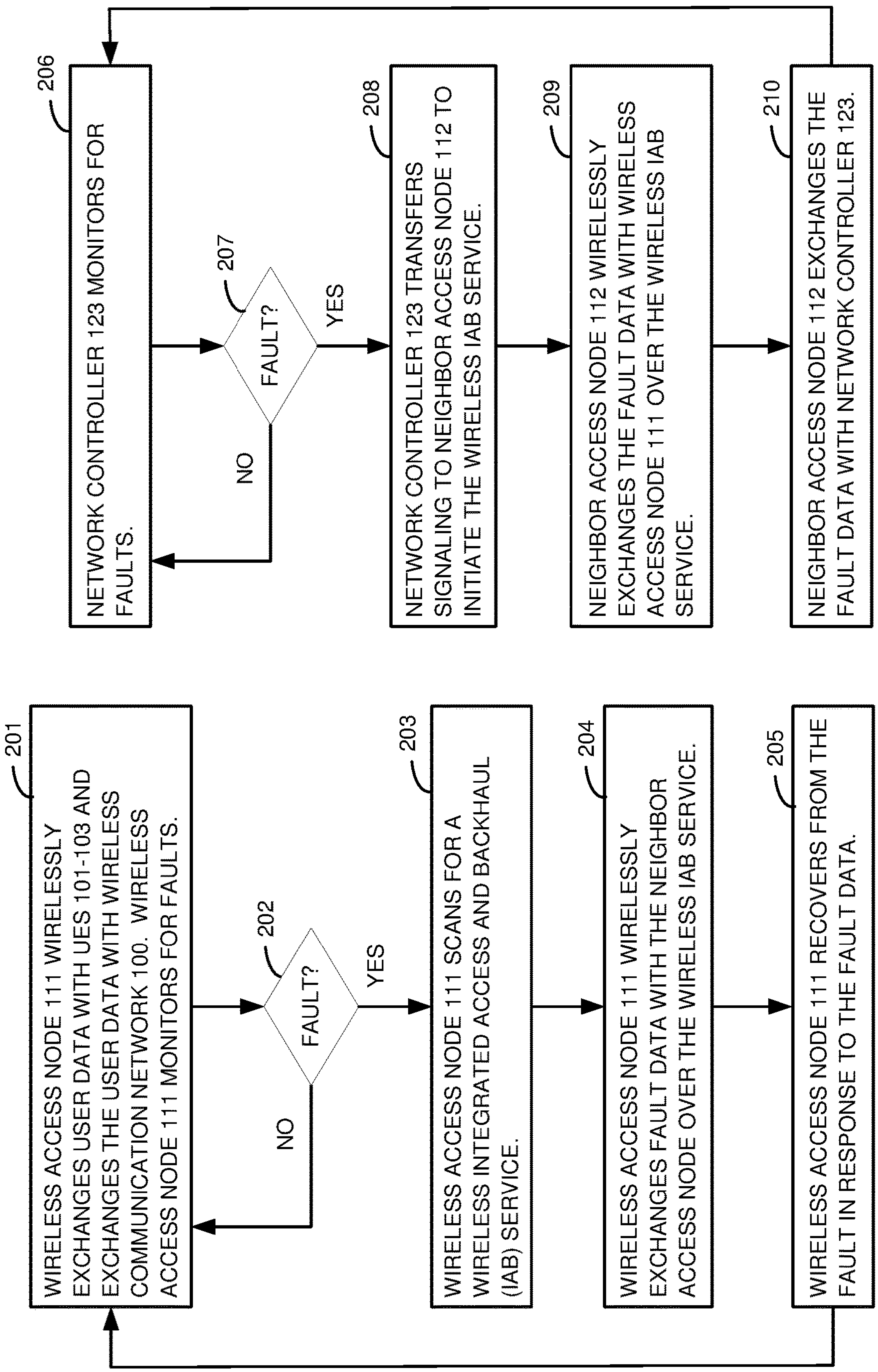

201
WIRELESS ACCESS NODE 111 WIRELESSLY EXCHANGES USER DATA WITH UES 101-103 AND EXCHANGES THE USER DATA WITH WIRELESS COMMUNICATION NETWORK 100. WIRELESS ACCESS NODE 111 MONITORS FOR FAULTS.
202
FAULT?
NO
YES
203
WIRELESS ACCESS NODE 111 SCANS FOR A WIRELESS INTEGRATED ACCESS AND BACKHAUL (IAB) SERVICE.
204
WIRELESS ACCESS NODE 111 WIRELESSLY EXCHANGES FAULT DATA WITH THE NEIGHBOR ACCESS NODE OVER THE WIRELESS IAB SERVICE.
205
WIRELESS ACCESS NODE 111 RECOVERS FROM THE FAULT IN RESPONSE TO THE FAULT DATA.
206
NETWORK CONTROLLER 123 MONITORS FOR FAULTS.
207
FAULT?
NO
YES
208
NETWORK CONTROLLER 123 TRANSFERS SIGNALING TO NEIGHBOR ACCESS NODE 112 TO INITIATE THE WIRELESS IAB SERVICE.
209
NEIGHBOR ACCESS NODE 112 WIRELESSLY EXCHANGES THE FAULT DATA WITH WIRELESS ACCESS NODE 111 OVER THE WIRELESS IAB SERVICE.
210
NEIGHBOR ACCESS NODE 112 EXCHANGES THE FAULT DATA WITH NETWORK CONTROLLER 123.

FIGURE 2

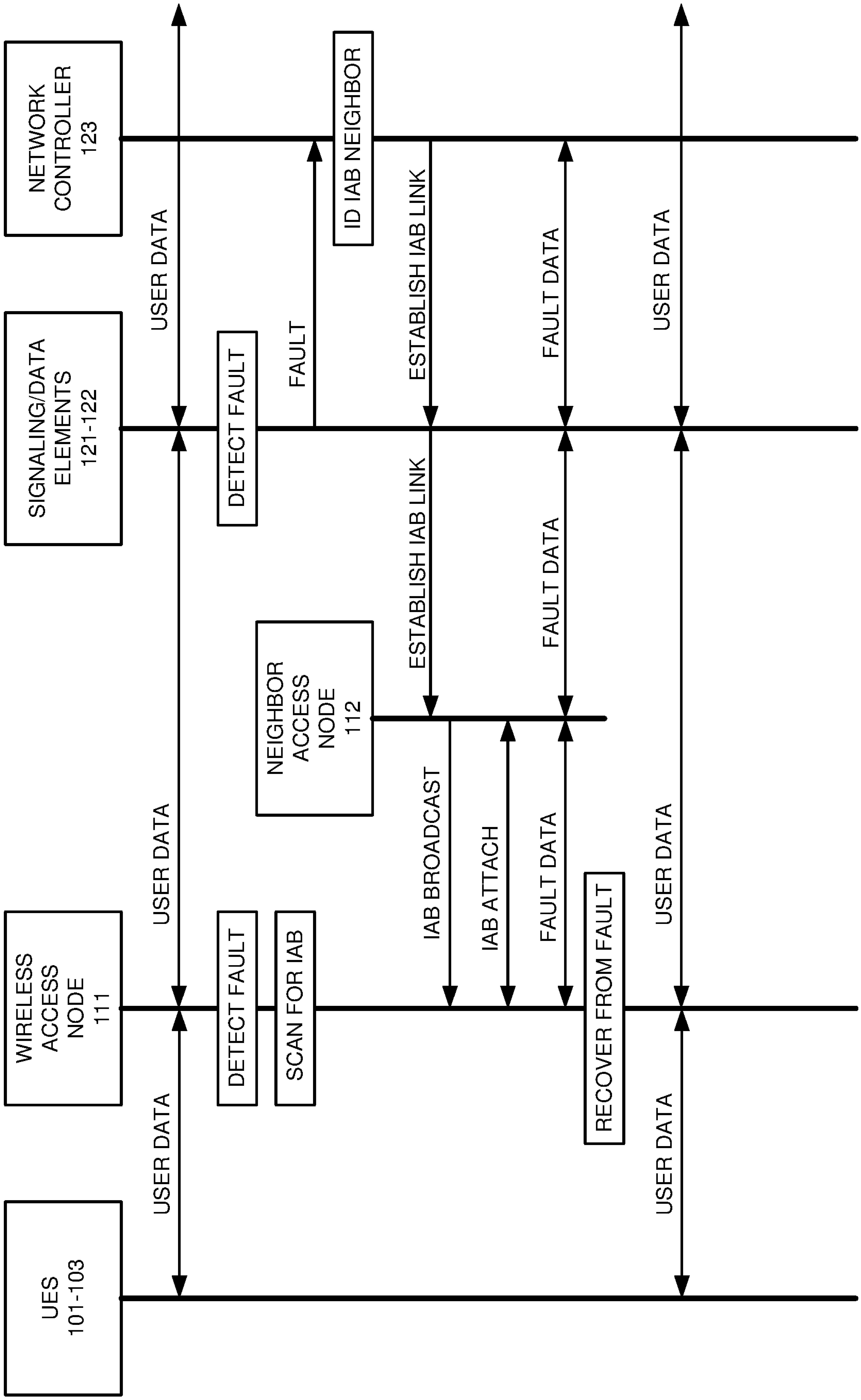

UES
101-103
WIRELESS ACCESS NODE 111
NEIGHBOR ACCESS NODE 112
SIGNALING/DATA ELEMENTS 121-122
NETWORK CONTROLLER 123
USER DATA
USER DATA
USER DATA
DETECT FAULT
SCAN FOR IAB
DETECT FAULT
FAULT
ID IAB NEIGHBOR
ESTABLISH IAB LINK
ESTABLISH IAB LINK
IAB BROADCAST
IAB ATTACH
FAULT DATA
FAULT DATA
FAULT DATA
RECOVER FROM FAULT
USER DATA
USER DATA
USER DATA

FIGURE 3

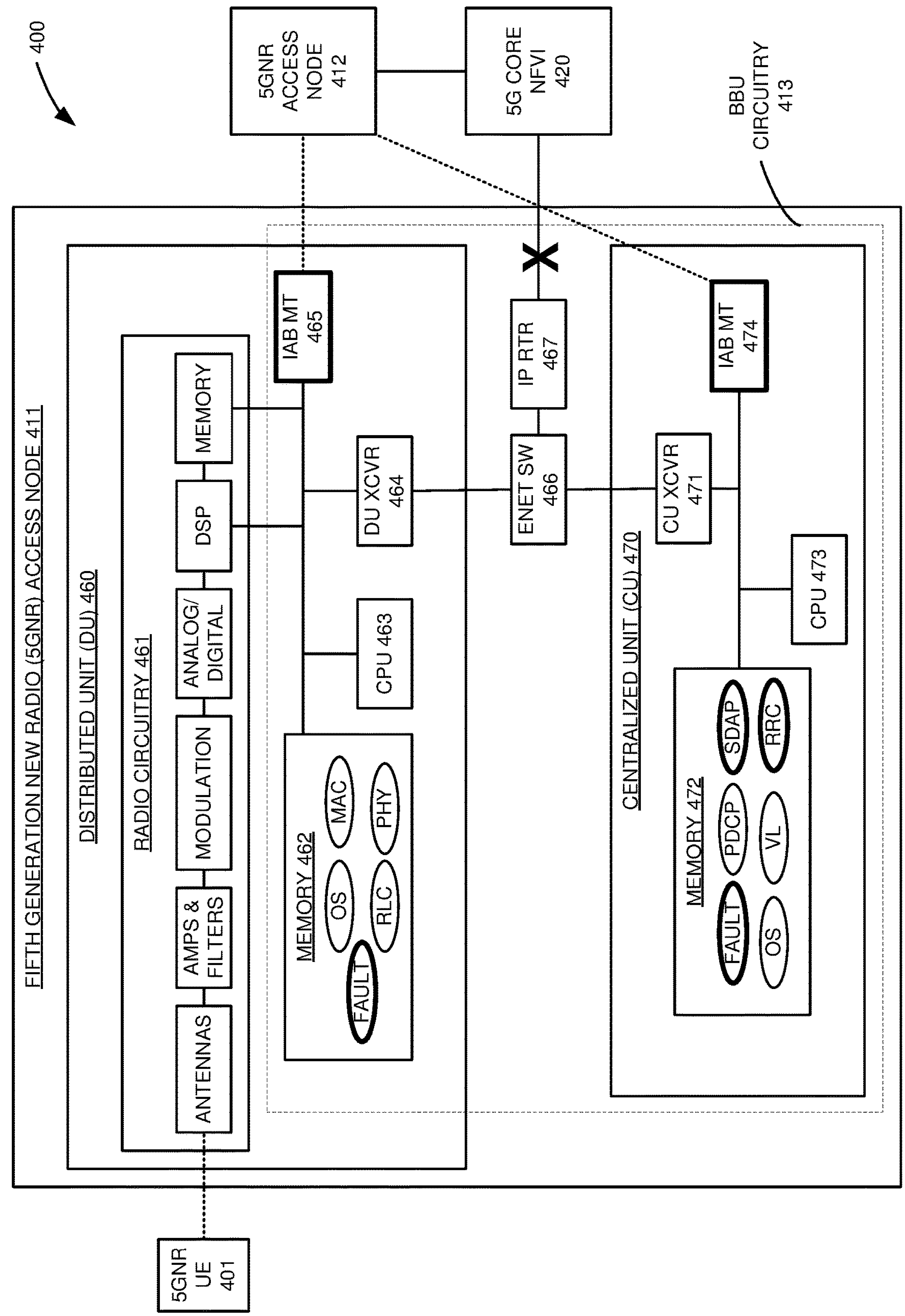
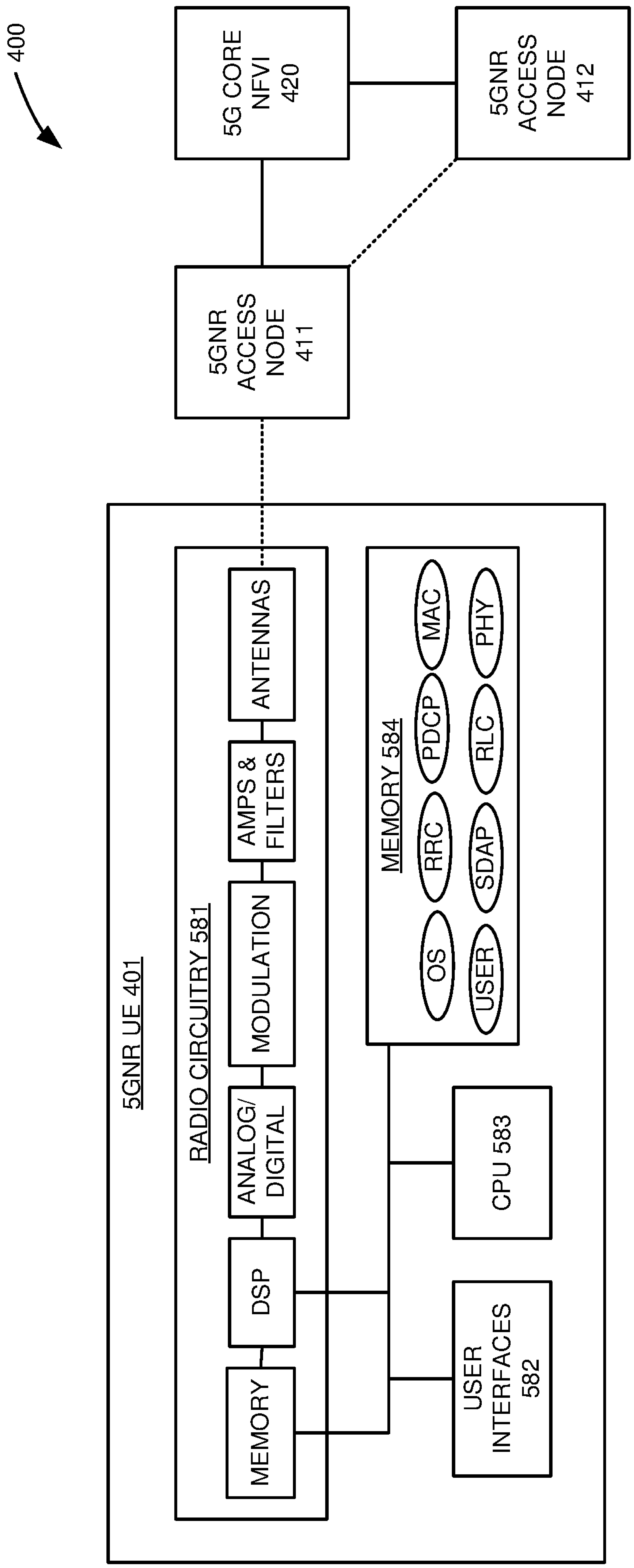

400
5GNR ACCESS NODE 412
5G CORE NFVI 420
BBU CIRCUITRY 413
FIFTH GENERATION NEW RADIO (5GNR) ACCESS NODE 411
DISTRIBUTED UNIT (DU) 460
RADIO CIRCUITRY 461
ANTENNAS
AMPS & FILTERS
MODULATION
ANALOG/ DIGITAL
DSP
MEMORY
IAB MT 465
DU XCVR 464
CPU 463
MEMORY 462
FAULT
OS
MAC
RLC
PHY
IP RTR 467
ENET SW 466
CENTRALIZED UNIT (CU) 470
IAB MT 474
CU XCVR 471
CPU 473
MEMORY 472
FAULT
OS
PDCP
VL
SDAP
RRC
5GNR UE 401

FIGURE 4


400
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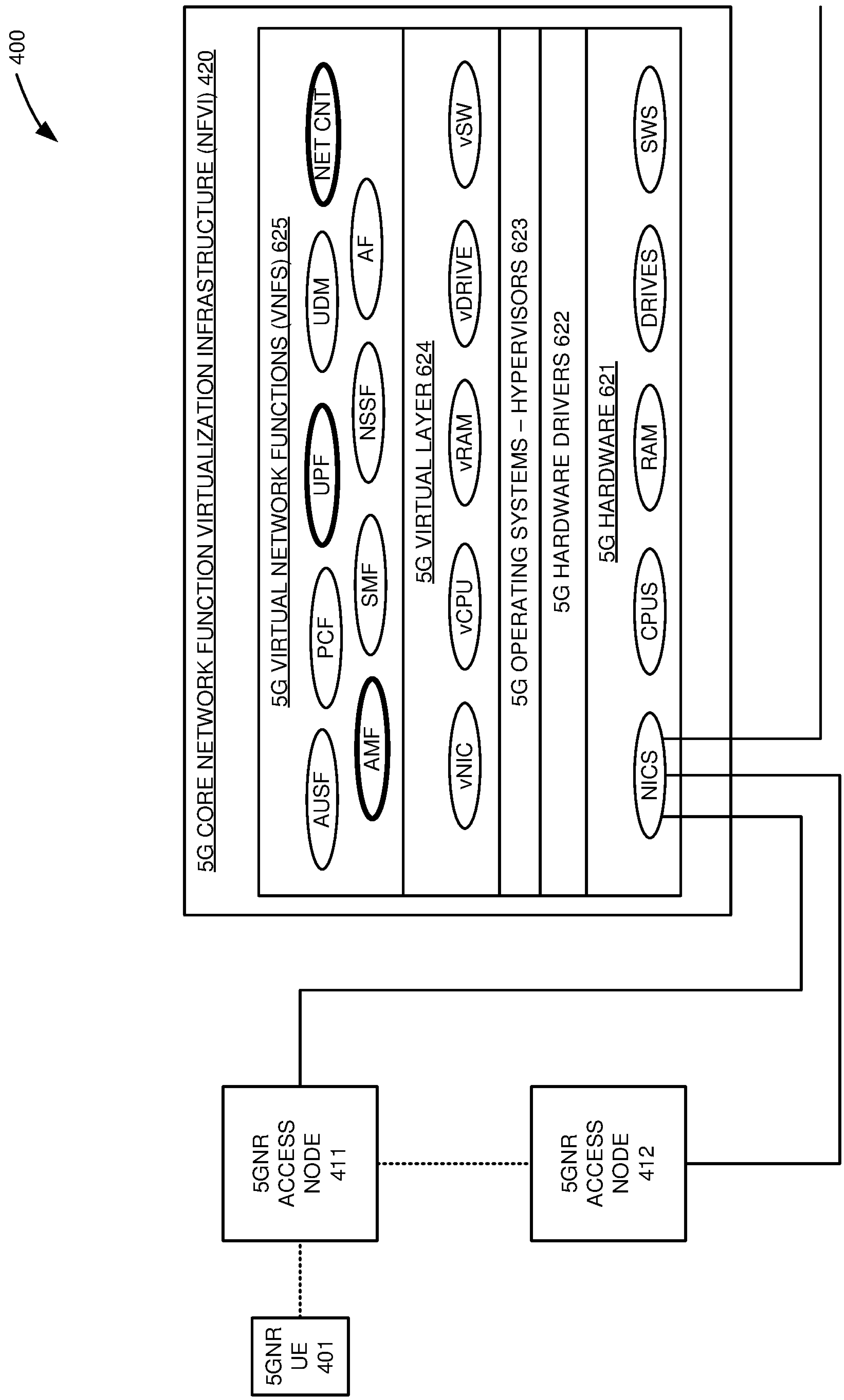
5GNR ACCESS NODE 412
5GNR ACCESS NODE 411
5GNR UE 401
RADIO CIRCUITRY 581
MEMORY
DSP
ANALOG/ DIGITAL
MODULATION
AMPS & FILTERS
ANTENNAS
MEMORY 584
OS
USER
RRC
SDAP
PDCP
RLC
MAC
PHY
CPU 583
USER INTERFACES 582

FIGURE 5


400
5G CORE NETWORK FUNCTION VIRTUALIZATION INFRASTRUCTURE (NFVI) 420
5G VIRTUAL NETWORK FUNCTIONS (VNFS) 625
AUSF
AMF
PCF
SMF
UPF
NSSF
UDM
AF
NET CNT
5G VIRTUAL LAYER 624
vNIC
vCPU
vRAM
vDRIVE
vSW
5G OPERATING SYSTEMS – HYPERVISORS 623
5G HARDWARE DRIVERS 622
5G HARDWARE 621
NICS
CPUS
RAM
DRIVES
SWS
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5GNR ACCESS NODE 412
5GNR UE 401

FIGURE 6

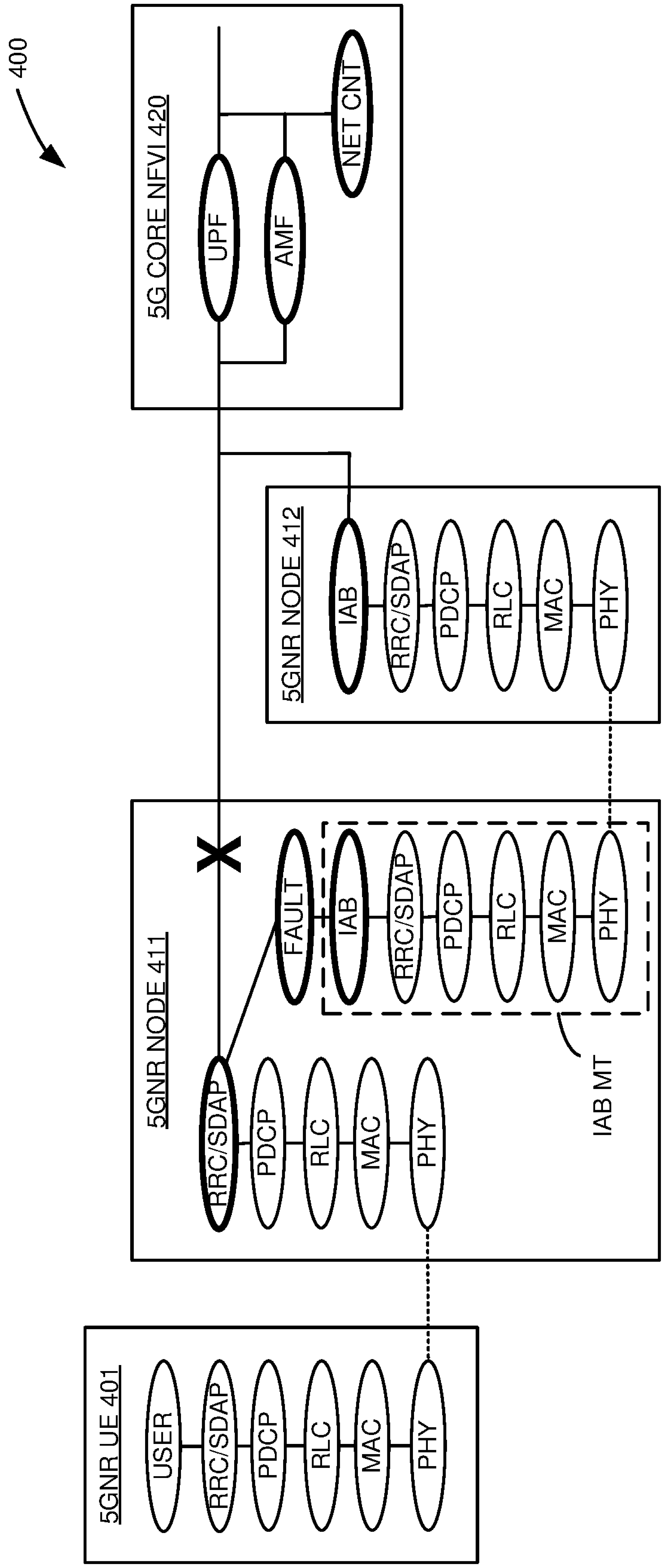
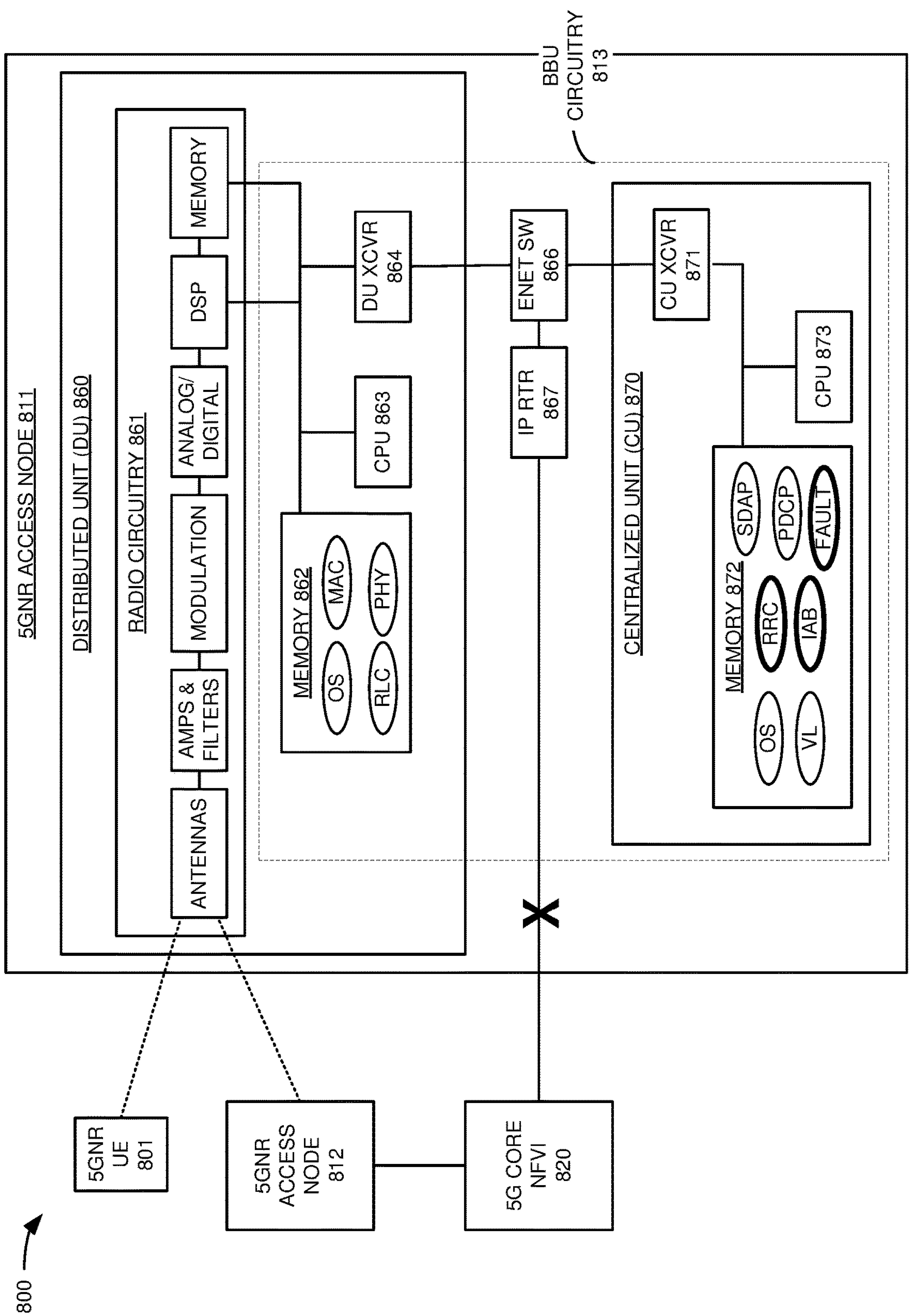

400
5G CORE NFVI 420
UPF
AMF
NET CNT
5GNR NODE 412
IAB
RRC/SDAP
PDCP
RLC
MAC
PHY
5GNR NODE 411
FAULT
IAB
RRC/SDAP
PDCP
RLC
MAC
PHY
RRC/SDAP
PDCP
RLC
MAC
PHY
IAB MT
5GNR UE 401
USER
RRC/SDAP
PDCP
RLC
MAC
PHY

FIGURE 7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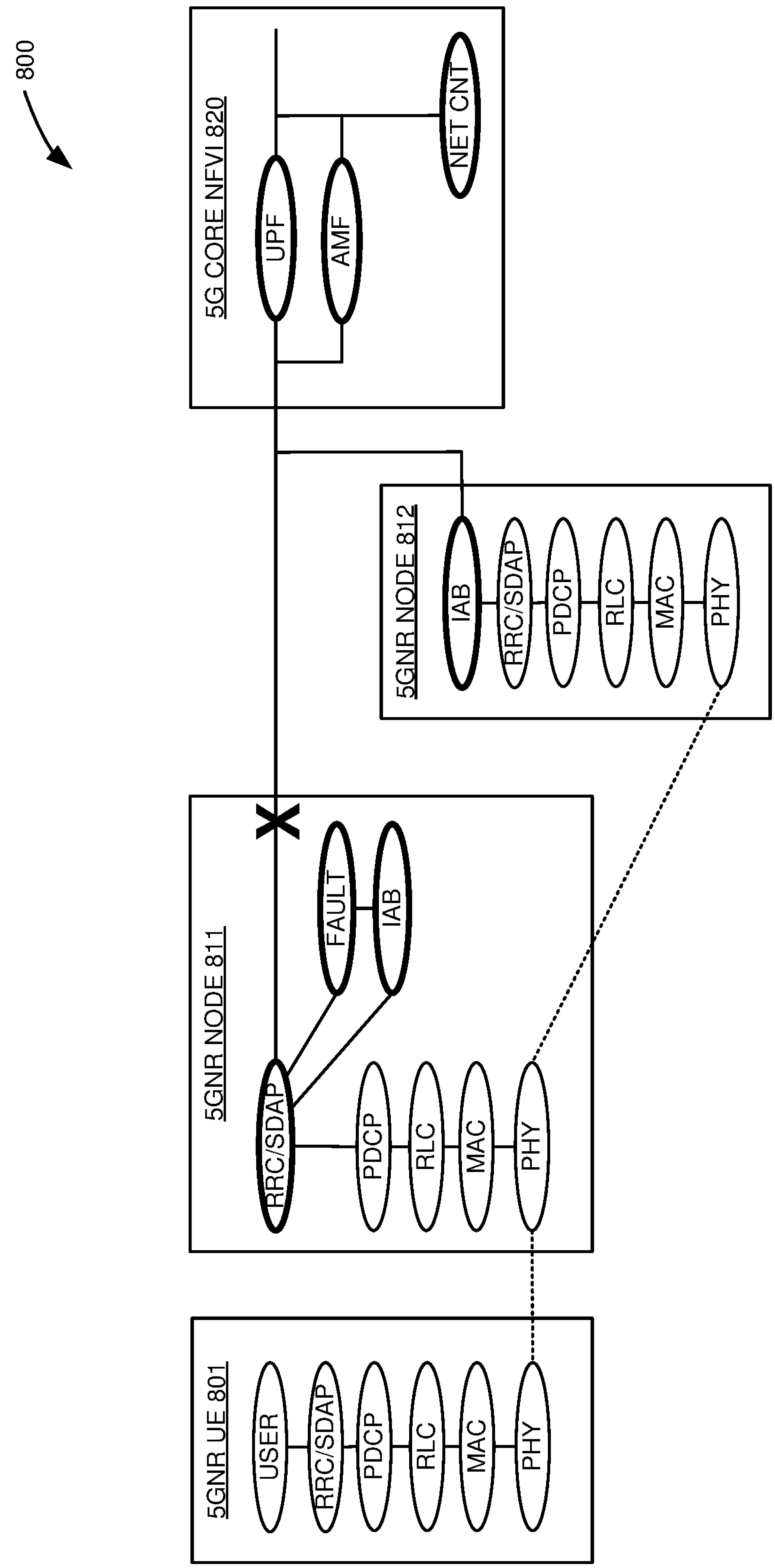
AMPS & FILTERS
MODULATION
ANALOG/ DIGITAL
DSP
MEMORY
MEMORY 862
OS
RLC
MAC
PHY
CPU 863
DU XCVR 864
ENET SW 866
IP RTR 867
BBU CIRCUITRY 813
CENTRALIZED UNIT (CU) 870
CU XCVR 871
CPU 873
MEMORY 872
OS
VL
RRC
IAB
SDAP
PDCP
FAULT
5GNR UE 801
5GNR ACCESS NODE 812
5G CORE NFVI 820
800

FIGURE 8


800
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UPF
AMF
NET CNT
5GNR NODE 812
IAB
RRC/SDAP
PDCP
RLC
MAC
PHY
5GNR NODE 811
FAULT
IAB
RRC/SDAP
PDCP
RLC
MAC
PHY
5GNR UE 801
USER
RRC/SDAP
PDCP
RLC
MAC
PHY

FIGURE 9

WIRELESS ACCESS NODE FAULT RECOVERY USING INTEGRATED ACCESS AND BACKHAUL

TECHNICAL BACKGROUND

Wireless communication networks provide wireless data services to wireless user devices. Exemplary wireless data services include machine-control, internet-access, media-streaming, and social-networking. Exemplary wireless user devices comprise phones, computers, vehicles, robots, and sensors. The wireless communication networks have wireless access nodes that exchange wireless signals with the wireless user devices using wireless network protocols. Exemplary wireless network protocols include Institute of Electrical and Electronic Engineers (IEEE) 802.11 (WIFI), Long Term Evolution (LTE), Fifth Generation New Radio (5GNR), and Low-Power Wide Area Network (LP-WAN).

The wireless access nodes are coupled to the wireless communication networks over backhaul links. The backhaul links use data communication protocols like Time Division Multiplex (TDM), IEEE 802.3 (ethernet), Internet Protocol (IP), and the like. The backhaul links typically use physical media like metal or glass. To extend the range of their wireless data services, the wireless communication networks are deploying wireless backhaul links. The wireless backhaul links use wireless network protocols like WIFI, LTE, and 5GNR. The Third Generation Partnership Project (3GPP) Technical Report (TR) 38.874 describes wireless Integrated Access and Backhaul (IAB) for wireless communication networks. 3GPP TR 38.874 specifies the IAB Mobile Terminal (MT) that provides wireless connectivity to a wireless access node over a wireless backhaul link. The IAB MT may be configured and operate like a wireless user device, but the IAB MT serves a wireless access node and not an end-user.

Unfortunately, wireless access nodes experience network faults that degrade or terminate their wireless data services. For example, an IP router or ethernet switch in a wireless access node may crash and become non-responsive. IAB describes techniques to discover and use alternative wireless backhaul links to bypass these faults. Technicians and troubleshooting systems are then used to fix the bypassed fault. IAB and the IAB Mobile Terminal (MTs) have not been efficiently and effectively used by wireless access nodes and wireless communication networks to fix these types of network faults.

TECHNICAL OVERVIEW

In a wireless access node, a baseband unit (BBU) detects a fault and responsively directs an Integrated Access and Backhaul (IAB) Mobile Terminal (MT) to scan for a wireless IAB service. The IAB MT scans for the wireless IAB service and establishes a wireless IAB link. The BBU exchanges fault data with the IAB MT. The IAB MT wirelessly exchanges the fault data with a neighbor access node over the wireless IAB link. The BBU recovers from the fault in response to the fault data.

DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a wireless communication network that uses Integrated Access and Backhaul (IAB) to recover from wireless access node faults.

FIG. **2** illustrates the operation of the wireless communication network to use IAB to recover from wireless access node faults.

FIG. **3** illustrates the operation of the wireless communication network to use IAB to recover from wireless access node faults.

FIG. **4** illustrates a Fifth Generation New Radio (5GNR) access node in a Fifth Generation (5G) wireless network that uses IAB to recover from 5GNR access node faults.

FIG. **5** illustrates a 5GNR User Equipment (UE) in the 5G wireless network.

FIG. **6** illustrates a 5G Core NFVI in the 5G wireless network.

FIG. **7** illustrates the operation of the 5G wireless network to use IAB to recover from 5GNR access node faults.

FIG. **8** illustrates another 5GNR access node in another 5G wireless network that uses IAB to recover from 5GNR access node faults.

FIG. **9** illustrates the operation of the other 5G wireless network to use IAB to recover from 5GNR access node faults.

DETAILED DESCRIPTION

FIG. **1** illustrates wireless communication network **100** that uses Integrated Access and Backhaul (IAB) to recover from wireless access node faults. Wireless communication network **100** comprises User Equipment (UEs) **101-106**, wireless access node **111**, neighbor access node **112**, signaling element **121**, data element **122**, and network controller **123**. Wireless communication network **100** serves UE **103-106** with wireless data services like internet-access, messaging, conferencing, machine control, or some other wireless networking product. UEs **101-103** might be phones, computers, robots, vehicles, or some other data appliances with wireless communication circuitry.

UEs **101-103** and wireless access node **111** are coupled over wireless links **131**. UEs **104-106** and neighbor access node **112** are coupled over wireless links **132**. To recover from faults, wireless access node **111** and neighbor access node **112** are coupled over wireless IAB link **133**. Links **131-133** use Fifth Generation New Radio (5GNR), Long Term Evolution (LTE), IEEE 802.11 (WIFI), Low-Power Wide Area Network (LP-WAN), or some other wireless communication protocol. Links **131-133** use electromagnetic frequencies in the low-band, mid-band, high-band, or some other part of the electromagnetic spectrum.

Wireless access node **111** and signaling element **121** are coupled over backhaul link **141**. Wireless access node **111** and data element **122** are coupled over backhaul link **142**. Neighbor access node **112** and signaling element **121** are coupled over backhaul link **143**. Neighbor access node **112** and data element **122** are coupled over backhaul link **144**. Signaling element **121** is coupled to external systems over data link **145**. Data element **122** is coupled to external systems over data link **146**. Signaling element **121** and data element **122** are coupled over network link **147**. Signaling element **121** and network controller **123** are coupled over network link **148**. Data element **122** and network controller **123** are coupled over network link **149**. Links **141-144** use Institute of Electrical and Electronic Engineers (IEEE) 802.3 (Ethernet), Time Division Multiplex (TDM), Data Over Cable System Interface Specification (DOCSIS), Internet Protocol (IP), 5GNR, WIFI, LTE, LP-WAN, or some other data communication protocol. Links **145-146** use TDM, Ethernet, IP, 5GNR or some other data communication protocol. Links **147-149** use TDM, Ethernet, IP, 5GNR, virtual switching, inter-processor communications, or some other data communication protocol.

Access nodes **111-112** comprise radio circuitry and Baseband Unit (BBU) circuitry. The radio circuitry comprises antennas, filters, amplifiers, analog-to-digital interfaces, microprocessors, memory, software, transceivers, bus circuitry, and the like. The BBU circuitry comprises microprocessors, memory, software, transceivers, and bus circuitry, and the like. The microprocessors comprise Digital Signal Processors (DSP), Central Processing Units (CPUs), Graphical Processing Units (GPUs), Application-Specific Integrated Circuits (ASICs), and/or the like. The memories comprise Random Access Memory (RAM), flash circuitry, disk drives, and/or the like. The memories store software like operating systems and network applications.

Signaling element **121**, data element **122**, and network controller **123** comprise processing circuitry like microprocessors, memory, software, transceivers, and bus circuitry. The microprocessors comprise CPU, GPUs, ASICs, and/or the like. The memories comprise RAM, flash circuitry, disk drives, and/or the like. The memories store software like operating systems, virtual layers, and network applications. Signaling element **121** comprises an Access and Mobility Management Function (AMF), Session Management Function (SMF), Mobility Management Entity (MME), Software-Defined Network (SDN) controller, or some other control-plane processor. Data element **122** comprises a User Plane Function (UPF), Serving Gateway (SGW), Packet Data Network Gateway (PGW), SDN packet processor, or some other data-plane machine. Network controller **123** comprises a Technical Assistance Center (TAC), Fault Management System (FMS), or some other fault recovery computer system.

The BBU circuitry in wireless access node **111** exchanges network signaling with signaling element **121** over backhaul link **141**. Signaling element **121** exchanges network signaling with data element **122** over network link **147**. In response to the network signaling. The radio circuitry in wireless access node **111** wirelessly exchanges user data with UEs **101-103** over links **131**. The radio circuitry and the BBU circuitry in wireless access node **111** exchange the user data. The BBU circuitry in wireless access node **111** exchanges the user data with data element **122** over backhaul link **142**. Data element **122** exchanges the user data with other systems over data link **146**.

Neighbor access node **112** exchanges network signaling with signaling element **121** over backhaul link **143**. Signaling element **121** exchanges network signaling with data element **122** over network link **147**. In response to the network signaling, neighbor access node **112** wirelessly exchanges user data with UEs **104-106** over links **132**. Neighbor access node **112** exchanges the user data with data element **122** over backhaul link **144**. Data element **122** exchanges the user data with other systems over data link **146**.

A fault occurs in wireless access node **111** that inhibits backhaul communications. For example, a cell-site router or ethernet switch in wireless access node **111** may crash. Wireless access node **111** detects the fault, and in response, the radio circuitry scans for wireless IAB service. Typically, the BBU circuitry in wireless access node **111** initially detects the fault by sensing a loss of communications over backhaul links **141-142**.

Signaling element **121** and/or data element **122** detect the fault and responsively transfer fault information to network controller **123**. Typically, elements **121-122** initially detect the fault by sensing a loss of communications over backhaul links **141-142**. Network controller **123** detects the fault in response to the fault information and selects neighbor access node **112** to help with fault recovery. For example, network controller **123** might host a data structure that translates a communication loss with wireless access node **111** into the ID for neighbor node **112**. Network controller **123** may process network topology data and access node status to select neighbor access node **112** based on its physical proximity to wireless access node **111** and based on normal operational status for backhaul links **143-144**.

Network controller **123** transfers network signaling to neighbor access node **112** to initiate wireless IAB service over elements **121-122** and backhaul links **143-144**. In response to the signaling, neighbor access node **112** wirelessly transmits an IAB broadcast to identify its IAB service. The radio circuitry in wireless access node **111** is scanning for and receives the IAB broadcast. In response to receiving the IAB broadcast, the radio circuitry in wireless access node **111** exchanges IAB attachment signaling with neighbor access node **112** to establish wireless IAB link **133**.

Wireless access node **111** and/or neighbor access node **112** report IAB link **133** to network controller **123** over elements **121-122** and backhaul links **143-144**. Network controller **123** and the BBU circuitry in wireless access node **111** exchange fault data to perform fault recovery. The exchange of the fault data occurs over wireless IAB link **133**, neighbor access node **112**, backhaul link **143** or **144**, element **121** or **122**, and network link **148** or **149**.

Wireless access node **111** recovers from the fault in response to the fault data. For example, the BBU circuitry in wireless access node **111** may reboot a hardware component and/or a software component responsive to the signaling. The hardware/software components may reside in cell-site routers, ethernet switches, or some other access node circuitry.

After the fault recovery, the BBU circuitry in wireless access node **111** exchanges network signaling with signaling element **121** over backhaul link **141**. Signaling element **121** exchanges network signaling with data element **122** over network link **147**. In response to the network signaling, the radio circuitry in wireless access node **111** wirelessly exchanges user data with UEs **101-103** over links **131**. The radio circuitry exchanges the user data with the BBU circuitry in wireless access node **111**. The BBU circuitry in wireless access node **111** exchanges the user data with data element **122** over backhaul link **142**. Data element **122** exchanges the user data with other systems over data link **146**.

Advantageously, wireless communication network **100** efficiently and effectively uses IAB to fix network faults at wireless access node **111**.

In some examples, wireless access node **111** comprises an IAB Mobile Terminal (MT). The IAB MT is similar to UEs **101-106** but the IAB MT is adapted to serve IAB link **133** to wireless access node **111**. In these examples, the BBU circuitry in wireless access node **111** directs the IAB MT to scan for the wireless IAB service in response to the fault. The IAB MT processes a stored list of IAB frequencies to scan the frequencies and detect an IAB broadcast from neighbor access node **112** at one of the IAB frequencies. The IAB MT attaches to the wireless IAB service responsive to the IAB broadcast. The BBU circuitry in wireless access node then exchanges fault data with network controller **123** over the IAB MT, IAB link **133**, neighbor access node **112**, backhaul link **143/144**, element **121/122**, and network link **148/149**.

In other examples, the radio circuitry in wireless access node **111** that serves UEs **101-103** over wireless links **131** also handles IAB link **133**. The radio circuitry scans for the wireless IAB service in response to BBU instructions for the fault. The radio circuitry attaches to the wireless IAB service responsive to the IAB broadcast. The BBU circuitry in wireless access node **111** then exchanges fault data with network controller **123** over the radio circuitry, IAB link **133**, neighbor access node **112**, backhaul link **143/144**, element **121/122**, and network link **148/149**.

FIG. **2** illustrates the operation of wireless communication system **100** to use IAB to recover from wireless access node faults. Wireless access node **111** wirelessly exchanges user data with UEs **101-103** and exchanges the user data with wireless communication network **100** (**201**). Wireless access node **111** monitors for faults (**201**). When wireless access node **111** detects a fault (**202**), wireless access node **111** scans for a wireless IAB service (**203**). Wireless access node **111** wirelessly exchanges fault data with neighbor access node **112** over IAB link **133** (**204**). Wireless access node **111** recovers from the fault in response to the fault data (**205**). After fault recovery, the operation in wireless access node **111** repeats (**201**).

Contemporaneously with operations **201-205**, network controller **123** monitors for faults (**206**). When network controller **123** detects the fault (**207**), network controller **123** transfers network signaling to neighbor access node **112** to initiate the wireless IAB service (**208**). Neighbor access node **112** wirelessly exchanges the fault data with wireless access node **111** over IAB link **133** (**209**). Neighbor access node **112** exchanges the fault data with network controller (**210**). The contemporaneous operation then repeats (**206**).

FIG. **3** illustrates the operation of the wireless communication system **100** to use IAB to recover from wireless access node faults. UEs **101-103** and wireless access node **111** wirelessly exchange user data. Wireless access node **111** exchanges the user data with data element **122**. Data element **122** exchanges the user data with other systems. Wireless access node **111** detects a fault and responsively scans for wireless IAB service.

Signaling element **121** or data element **122** also detect the fault and responsively transfer fault information to network controller **123**. Network controller **123** selects neighbor access node **112** to help with fault recovery based on the fault information. Network controller **123** transfers network signaling to establish the IAB link to signaling element **121**. Signaling element **121** transfers network signaling to establish the IAB link to neighbor access node **112**. In response to the network signaling, neighbor access node **112** wirelessly transmits an IAB broadcast to identify its IAB service—typically on a short and periodic basis. Wireless access node **111** scans and receives the IAB broadcast. In response to receiving the IAB broadcast, wireless access node **111** and neighbor access node **112** exchange IAB attachment signaling to establish wireless IAB link **133**.

Wireless access node **111** and network controller **123** exchange fault data over IAB link **133** served by neighbor access node **112**. Wireless access node **111** recovers from the fault in response to the fault data. After the fault recovery, UEs **101-103** wirelessly exchange user data with wireless access node **111**. Wireless access node **111** exchanges the user data with data element **122**. Data element **122** exchanges the user data with other systems.

FIG. **4** illustrates Fifth Generation New Radio (5GNR) access node **411** in Fifth Generation (5G) wireless network **400** that uses IAB to recover from 5GNR access node faults. 5G network **400** is an example of wireless communication network **100**, although network **100** may differ. 5G network **400** comprises UE **401**, 5GNR access nodes **411-412**, and 5G core Network Function Virtualization Infrastructure (NFVI) **420**. 5GNR access node **411** is an example of access nodes **111-112**, although access nodes **111-112** may differ.

5GNR access node **411** comprises Distributed Unit (DU) **460**, ethernet switch (ENET SW) **466**, Internet Protocol router (IP RTR) **467**, and Centralized Unit (CU) **470**. DU **460** comprises radio circuitry **461**, memory **462**, CPU **463**, DU XCVR **464**, and IAB Mobile Terminal (MT) **465** that are coupled over bus circuitry. XCVR refers to transceiver. Radio circuitry **461** comprises antennas, amplifiers (AMPS), filters, modulation, analog-to-digital interfaces, DSP, and memory that are coupled over bus circuitry. CU **470** comprises CU XCVR **471**, memory **472**, CPU **473**, and IAB MT **474** that are coupled over bus circuitry.

5GNR access node **411** comprises radio circuitry **461** and BBU circuitry **413**. BBU circuitry **413** comprises CU **470**, Ethernet switch **466**, IP router **467**, and a portion of DU **460** (memory **462**, CPU **463**, DU XCVR **464**, IAB MT **465**, and associated bus circuitry). UE **401** is wirelessly coupled to the antennas in DU **460**. DU XCVR **464** is coupled to ethernet switch **466**. Ethernet switch **466** is coupled to IP router **467** and CU XCVR **471**. IP router **467** is coupled to 5G core NFVI **420**. IAB MTs **465** and **474** can be wirelessly linked to 5GNR access node **412** using IAB.

In DU **460**, memory **462** stores operating system (OS), Physical Layer (PHY), Media Access Control (MAC), Radio Link Control (RLC), and fault recovery application (FAULT). In CU **470**, memory **472** stores an operating system, virtual layer (VL), Packet Data Convergence Protocol (PDCP), Radio Resource Control (RRC), Service Data Adaptation Protocol (SDAP), and fault recovery application. The virtual layer comprises hypervisor modules, virtual switches, virtual CPUs, and/or the like. CPU **473** in CU **470** executes the PDCP, RRC, and SDAP to drive the exchange of user data and network signaling between 5G core NFVI **420** and DU **460**—including fault detection. CPU **463** in DU **460** executes the PHY, MAC, and RLC to drive the transfer of user data and network signaling between CU **470** and UE **401**—including fault detection. The functionality split of the network applications (PHY, MAC, RLC, PDCP, RRC, SDAP) between DU **460** and CU **470** may vary.

In radio circuitry **461** of DU **460**, the antennas receive wireless 5GNR signals from 5GNR UE **401** that transport the Uplink (UL) signaling and data. The antennas transfer corresponding electrical UL signals through duplexers to the amplifiers. The amplifiers boost the received UL signals for filters which attenuate unwanted energy. In modulation, demodulators down-convert the UL signals from their carrier frequency. The analog/digital interfaces convert the analog UL signals into digital UL signals for the DSP. The DSP recovers UL 5GNR symbols from the UL digital signals. In DU **460** and CU **470**, CPU **463** and CPU **473** execute the network applications to process the UL 5GNR symbols and recover the UL signaling and data. In CU **470**, CPU **473** executes the RRC to generate corresponding UL N2 signaling and UL N3 data. CU **470** transfers the UL N2 signaling to Access and Mobility Management Functions (AMFs) in 5G core NFVI **420** over ethernet switch **466** and IP router **467**. CU **470** transfers the UL N3 data to User Plane Functions (UPFs) in 5G core NFVI **420** over ethernet switch **466** and IP router **467**.

In CU **470**, CU XCVR **471** receives Downlink (DL) N2 signaling from the AMFs and DL N3 data from the UPFs in 5G core NFVI **420** over ethernet switch **466** and IP router **467**. In CU **470** and DU **460**, CPU **473** and **463** execute the network applications to generate corresponding DL signaling and data. In CU **470** and DU **460**, CPU **473** and CPU **463** execute the network applications to process the DL signaling and data to generate DL 5GNR symbols that carry the DL signaling and data. In DU **460**, the DSP processes the DL 5GNR symbols to generate corresponding digital signals for the analog-to-digital interfaces. The analog-to-digital interfaces convert the digital DL signals into analog DL signals for modulation. Modulation up-converts the DL signals to their carrier frequency. The amplifiers boost the modulated DL signals for the filters which attenuate unwanted out-of-band energy. The filters transfer the filtered DL signals through duplexers to the antennas. The electrical DL signals drive the antennas to emit corresponding wireless 5GNR signals that transport the DL signaling and data to 5GNR UE **401**.

RRC functions comprise authentication, security, handover control, status reporting, Quality-of-Service (QoS), network broadcasts and pages, and network selection. SDAP functions comprise QoS marking and flow control. PDCP functions comprise LTE/5GNR allocations, security ciphering, header compression and decompression, sequence numbering and re-sequencing, de-duplication. RLC functions comprise Automatic Repeat Request (ARQ), sequence numbering and resequencing, segmentation and resegmentation. MAC functions comprise buffer status, power control, channel quality, Hybrid Automatic Repeat Request (HARM), user identification, random access, user scheduling, and QoS. PHY functions comprise packet formation/deformation, windowing/de-windowing, guard-insertion/guard-deletion, parsing/de-parsing, control insertion/removal, interleaving/de-interleaving, Forward Error Correction (FEC) encoding/decoding, rate matching/de-matching, scrambling/descrambling, modulation mapping/de-mapping, channel estimation/equalization, Fast Fourier Transforms (FFTs)/Inverse FFTs (IFFTs), channel coding/decoding, layer mapping/de-mapping, precoding, Discrete Fourier Transforms (DFTs)/Inverse DFTs (IDFTs), and Resource Element (RE) mapping/de-mapping.

A fault occurs in 5GNR access node **411**. For example, ethernet switch **466** or IP router **467** may fail. The RRC and/or SDAP in CU **470** detect the fault by sensing the loss of N2 signaling or N3 data and notifying the fault recovery application in CU **470** or DU **460**. In response to the fault, the fault recovery application in CU **470** and/or CU **460** directs IAB MT **474** and/or IAB MT **465** to scan for wireless IAB service. IAB MT **474** and/or **465** host a list of IAB frequencies to scan and eventually detect an IAB broadcast. In response to detecting the IAB broadcast, IAB MT **465** and/or IAB MT **474** wirelessly exchange IAB attachment signaling with 5GNR access node **512** and establish a wireless IAB link.

The fault recovery application and a network controller in 5G core NFVI **420** exchange fault data to perform fault recovery. The exchange of the fault data occurs over the wireless IAB link. The fault recovery application recovers from the fault in response to the fault data exchange with 5G core NFVI **420**. The fault recovery application may reboot ethernet switch **466**, IP router **467**, radio circuitry **461**, or their respective software components. After fault recovery, CPU **473** in CU **470** executes the PDCP, RRC, and SDAP to drive the exchange of user data and network signaling between 5G core NFVI **420** and DU **460**—including fault detection. CPU **463** in DU **460** executes the PHY, MAC, and RLC to drive the transfer of user data and network signaling between CU **470** and UE **401**—including fault detection.

FIG. **5** illustrates 5GNR UE **401** in 5G wireless network **400**. 5GNR UE **401** is an example of UEs **101-106**, although UEs **101-106** may differ. 5GNR UE **401** is similar to MTs **465** and **474**. UE **401** comprises radio circuitry **581**, user interfaces **582**, CPU **583**, and memory **484** which are interconnected over bus circuitry. Radio circuitry **581** comprises antennas, amplifiers, filters, modulation, analog-to-digital interfaces, DSP, and memory that are coupled over bus circuitry. The antennas in 5GNR UE **401** are coupled to 5GNR access node **411**. User interfaces **582** comprise graphic displays, machine controllers, sensors, cameras, transceivers, and/or some other user components. Memory **584** stores an operating system, user applications, and network applications. The network applications comprise PHY, MAC, RLC, PDCP, RRC and SDAP. CPU **583** executes the operating system, user applications, and network applications to exchange 5GNR signaling and data with 5GNR access node **411** over radio circuitry **581**.

FIG. **6** illustrates 5G Core NFVI **420** in 5G wireless network **400**, where NFVI refers to Network Function Virtualization Infrastructure. 5G core NFVI **420** is an example of signaling element **121**, data element **122**, and network controller **123**, although elements **121-122** and controller **123** may differ. 5G core NFVI **420** comprises 5G hardware **621**, 5G hardware drivers **622**, 5G operating systems and hypervisors **623**, 5G virtual layer **624**, and 5G Virtual Network Functions (VNFs) **625**. 5G hardware **621** comprises Network Interface Cards (NICs), CPUs, RAM, flash/disk drives, and data switches (SWS). 5G virtual layer **624** comprises virtual NICs (vNIC), virtual CPUs (vCPU), virtual RAM (vRAM), virtual Drives (vDRIVE), and virtual Switches (vSW). The NICs are coupled to 5GNR access nodes **411-412** and external systems over data links. 5G VNFs **625** comprise Authentication and Security Functions (AUSF), Policy Control Functions (PCF), Access and Mobility Management Functions (AMF), Session Management Functions (SMF), User Plane Functions (UPF), Unified Data Management (UDM), Network Slice Selection Functions (NSSF), Application Functions (AF), and Network Controller Functions (NET CNT). Other 5G network functions are typically present but are omitted for clarity. 5G hardware **621** executes 5G hardware drivers **622**, 5G operating systems and hypervisors **623**, 5G virtual layer **624**, and 5G VNFs **625** to serve the 5GNR UE **401** with data services.

The UPF and AMF detect faults by sensing a loss of communication with 5GNR access node **411**. The UPF and AMF notify the NET CNT of the fault for 5GNR access node **411**. The NET CNT selects 5GNR access node **412** (and possibly other access nodes) to start IAB service to fix the fault based on proximity and status. The NET CNT signals 5GNR access node **412** over the AMF or UPF to start IAB service for 5GNR access node **411** with a link back to the NET CNT. The NET CNT exchanges fault data with 5GNR access node **411**. The fault data from wireless access node **411** characterizes the failing system like a crashed ethernet switch, unresponsive IP router, or noisy radio. The NET CNT identifies recovery actions or scripts based on the fault characterization. The recovery actions or scripts may comprise instructions to reboot hardware components by removing their power supply or rebooting software components by reinstalling them from memory. The fault data sent to 5GNR access node **411** indicates the recovery actions or scripts.

FIG. **7** illustrates the operation of 5G wireless network **400** to use IAB to recover from 5GNR access node faults. In 5GNR UE **401**, the user application exchanges user data and signaling with the RRC/SDAP. The RRC/SDAP in UE **401** exchanges corresponding network signaling with the RRC/SDAP in 5GNR access node **411** over their PDCPs, RLCs, MACs, and PHYs. The RRC exchanges N2 signaling with the AMF. The SDAP exchanges N3 data with the UPF.

A fault occurs in 5GNR access node **411**. The RRC/SDAP detect the fault by sensing the loss of N2 signaling or N3 data. The RRC/SDAP notify the fault recovery application. In response, the fault recovery application directs an IAB MT (IAB) to establish an IAB link. The IAB MT configures its RRC, SDAP, PDCP, RLC, MAC, and PHY to handle IAB attachment and IAB links.

In 5G core NFVI **420**, the UPF detects the fault by sensing a loss of N3 data from 5GNR access node **411**. The AMF detects the fault by sensing a loss of N2 signaling from 5GNR access node **411**. The UPF and AMF notify the NET CNT of the fault for 5GNR access node **411**. The NET CNT selects 5GNR access node **412** (and possibly other access nodes) to start IAB service based on proximity and status. The NET CNT signals an IAB controller (IAB) in 5GNR access node **412** over the AMF or UPF to start IAB service for 5GNR access node **411** with a link back to the NET CNT.

The IAB controller in 5GNR access node **412** starts to broadcast IAB information over the RRC, PDCP, RLC, MAC, and PHY. The IAB controller in 5GNR access node **412** configures the RRC, SDAP, PDCP, RLC, MAC, and PHY to handle IAB attachment and IAB links over a portion of its wireless spectrum. The IAB broadcast and configuration may cycle on and off, have a short on cycle, and use a narrow amount of bandwidth.

One of IAB MTs **466** and **474** in 5GNR node **411** detects the IAB broadcast from 5GNR access node **412** over its RRC, PDCP, RLC, MAC, and PHY. The detecting IAB MT in 5GNR node **411** exchanges IAB attachment signaling with the IAB controller in 5GNR node **412** over their RRCs, PDCPs, RLCs, MACs, and PHYs. The IAB MT in 5GNR node **411** and the IAB controller in 5GNR node **412** establish a wireless IAB link over their RRCs, SDAPs, PDCPs, RLCs, MACs, and PHYs. The IAB controller in 5GNR node **412** couples the IAB link to the NET CNT in 5G core NFVI **420** over the UPF or AMF.

The fault recovery application in 5GNR node **411** and the NET CNT in 5G core NFVI **420** exchange fault data to perform fault recovery. The exchange of the fault data occurs over the IAB MT, the wireless IAB link, and 5GNR node **412**. The fault recovery application recovers from the fault in response to the fault data exchange with the NET CNT in 5G core NFVI **420**. After fault recovery, 5GNR access node **411** wirelessly exchanges user data and signaling with 5GNR UE **401** and also exchanges N2 signaling and N3 data with the AMF and UPF in 5G core NFVI **420**.

FIG. **8** illustrates 5GNR access node **811** in 5G wireless network **800** that uses IAB to recover from 5GNR access node faults. 5G network **800** is an example of wireless communication network **100**, although network **100** may differ. 5G network **800** comprises UE **801**, 5GNR access nodes **811**-**812**, and 5G core NFVI **820**. 5GNR access node **811** is an example of access nodes **111**-**112**, although access nodes **111**-**112** may differ. 5GNR access node **811** comprises Distributed Unit (DU) **860**, ethernet switch **865**, IP router **866**, and Centralized Unit (CU) **870**. DU **860** comprises radio circuitry **861**, memory **862**, CPU **863**, and DU XCVR **864** that are coupled over bus circuitry. Radio circuitry **861** comprises antennas, amplifiers, filters, modulation, analog-to-digital interfaces, DSP, and memory that are coupled over bus circuitry. CU **870** comprises CU XCVR **871**, memory **872**, and CPU **873** that are coupled over bus circuitry. In 5GNR access node **811**, BBU circuitry **813** comprises CU **870**, Ethernet switch **866**, IP router **867**, and a portion of DU **860** (memory **862**, CPU **863**, DU XCVR **864**, and associated bus circuitry).

5GNR communication network **800** and 5GNR access node **811** operate like 5GNR communication network **400** and 5GNR access node **411** except that 5GNR access node **811** uses radio circuitry **861** for wireless IAB service instead of an IAB MT. In DU **860**, memory **462** stores operating system, PHY, MAC, and RLC. In CU **870**, memory **872** stores an operating system, virtual layer, PDCP, RRC, SDAP, fault recovery application, and IAB controller. When a fault occurs in 5GNR access node **811**, the fault recovery application directs the IAB controller to use a portion of radio circuitry **861** for wireless IAB service. The IAB controller may host a list of IAB frequencies to scan and detect an IAB broadcast. In response to detecting an IAB broadcast, the IAB controller wirelessly exchanges IAB attachment signaling with 5GNR access node **812** over radio circuitry **861** and establishes a wireless IAB link with 5GNR access node **812** over radio circuitry **861**.

FIG. **9** illustrates the operation of 5G wireless network **800** to use IAB to recover from 5GNR access node faults. When the fault occurs in 5GNR access node **411**, the fault recovery application directs the IAB controller to establish an IAB link. The IAB controller configures the RRC, SDAP, PDCP, RLC, MAC, and PHY in CU **870** and DU **860** to handle IAB attachment and IAB links. The IAB controller in 5GNR node **811** detects the IAB broadcast from 5GNR access node **812** over radio circuitry **861** and the RRC, PDCP, RLC, MAC, and PHY. The IAB controller in 5GNR node **811** exchanges IAB attachment signaling with the IAB controller in 5GNR node **812** over their RRCs, PDCPs, RLCs, MACs, and PHYs. The IAB controller in 5GNR node **811** and the IAB controller in 5GNR node **812** establish a wireless IAB link over their RRCs, SDAPs, PDCPs, RLCs, MACs, and PHYs. The IAB controller in 5GNR node **812** couples the IAB link to the NET CNT in 5G core NFVI **420** over the UPF or AMF. The NET CNT and the fault recovery application use the IAB link to exchange fault data and recover from the fault.

The wireless data network circuitry described above comprises computer hardware and software that form special-purpose network circuitry to recover from wireless access node faults using IAB. The computer hardware comprises processing circuitry like CPUs, DSPs, GPUs, transceivers, bus circuitry, and memory. To form these computer hardware structures, semiconductors like silicon or germanium are positively and negatively doped to form transistors. The doping comprises ions like boron or phosphorus that are embedded within the semiconductor material. The transistors and other electronic structures like capacitors and resistors are arranged and metallically connected within the semiconductor to form devices like logic circuitry and storage registers. The logic circuitry and storage registers are arranged to form larger structures like control units, logic units, and Random-Access Memory (RAM). In turn, the control units, logic units, and RAM are metallically connected to form CPUs, DSPs, GPUs, transceivers, bus circuitry, and memory.

In the computer hardware, the control units drive data between the RAM and the logic units, and the logic units operate on the data. The control units also drive interactions with external memory like flash drives, disk drives, and the like. The computer hardware executes machine-level software to control and move data by driving machine-level inputs like voltages and currents to the control units, logic units, and RAM. The machine-level software is typically compiled from higher-level software programs. The higher-level software programs comprise operating systems, utilities, user applications, and the like. Both the higher-level software programs and their compiled machine-level software are stored in memory and retrieved for compilation and execution. On power-up, the computer hardware automatically executes physically-embedded machine-level software that drives the compilation and execution of the other computer software components which then assert control. Due to this automated execution, the presence of the higher-level software in memory physically changes the structure of the computer hardware machines into special-purpose network circuitry to recover from wireless access node faults using IAB.

The above description and associated figures teach the best mode of the invention. The following claims specify the scope of the invention. Note that some aspects of the best mode may not fall within the scope of the invention as specified by the claims. Those skilled in the art will appreciate that the features described above can be combined in various ways to form multiple variations of the invention. Thus, the invention is not limited to the specific embodiments described above, but only by the following claims and their equivalents.

What is claimed is:

1. A method of operating a wireless access node to recover from a fault, the method comprising:

a radio wirelessly exchanging user data with wireless user devices;

a baseband unit (BBU) exchanging the user data with a wireless communication network;

the BBU detecting the fault and responsively directing an Integrated Access and Backhaul (IAB) Mobile Terminal (MT) to scan for a wireless IAB service;

the IAB MT scanning for the wireless IAB service;

the BBU exchanging fault data with the IAB MT;

the IAB MT wirelessly exchanging the fault data with a neighbor access node over the wireless IAB service;

the BBU recovering from the fault in response to the fault data;

the radio wirelessly exchanging additional user data with wireless user devices; and

the BBU exchanging the additional user data with the wireless communication network.

2. The method of claim **1** wherein the BBU directing the IAB MT to scan for the wireless IAB service comprises a Radio Resource Control (RRC) indicating the fault to a fault recovery application and the fault recovery application signaling the IAB MT to establish an IAB link for the wireless IAB service.

3. The method of claim **1** wherein the IAB MT scanning for the wireless IAB service comprises the IAB MT processing a list of IAB frequencies and responsively detecting an IAB broadcast for the wireless IAB service from the neighbor access node at one of the IAB frequencies.

4. The method of claim **1** wherein the IAB MT wirelessly exchanging the fault data with the neighbor access node over the wireless IAB service comprises exchanging Fifth Generation New Radio (5GNR) signals with the neighbor access node.

5. The method of claim **1** wherein the IAB MT is in a Fifth Generation New Radio (5GNR) Distributed Unit (DU).

6. The method of claim **1** wherein the IAB MT is in a Fifth Generation New Radio (5GNR) Centralized Unit (CU).

7. The method of claim **1** wherein the IAB MT is in a Fifth Generation New Radio (5GNR) Distributed Unit (DU) and the BBU is in a 5GNR Centralized Unit (CU).

8. The method of claim **1** wherein the IAB MT is in a Fifth Generation New Radio (5GNR) Distributed Unit (DU) and the BBU is in the 5GNR DU.

9. The method of claim **1** wherein the BBU recovering from the fault comprises rebooting an Internet Protocol (IP) router responsive to the signaling.

10. The method of claim **1** wherein the BBU recovering from the fault comprises rebooting an ethernet switch responsive to the signaling.

11. A wireless access node to recover from a fault, the wireless access node comprising:

a radio wirelessly configured to exchange user data with wireless user devices;

a baseband unit (BBU) configured to exchange the user data with a wireless communication network;

the BBU configured to detect the fault and responsively direct an Integrated Access and Backhaul (IAB) Mobile Terminal (MT) to scan for a wireless IAB service;

the IAB MT configured to scan for the wireless IAB service;

the BBU configured to exchange fault data with the IAB MT;

the IAB MT configured to wirelessly exchange the fault data with a neighbor access node over the wireless IAB service;

the BBU configured to recover from the fault in response to the fault data;

the radio configured to wirelessly exchange additional user data with wireless user devices; and

the BBU configured to exchange the additional user data with the wireless communication network.

12. The wireless access node of claim **11** wherein the BBU comprises a Radio Resource Control (RRC) configured to indicate the fault to a fault recovery application and the fault recovery application configured to signal the IAB MT to establish an IAB link for the wireless IAB service.

13. The wireless access node of claim **11** wherein the IAB MT is configured to process a list of IAB frequencies and responsively detect an IAB broadcast for the wireless IAB service from the neighbor access node at one of the IAB frequencies.

14. The wireless access node of claim **11** wherein the IAB MT is configured to exchange Fifth Generation New Radio (5GNR) signals with the neighbor access node.

15. The wireless access node of claim **11** wherein the IAB MT is in a Fifth Generation New Radio (5GNR) Distributed Unit (DU).

16. The wireless access node of claim **11** wherein the IAB MT is in a Fifth Generation New Radio (5GNR) Centralized Unit (CU).

17. The wireless access node of claim **11** wherein the IAB MT is in a Fifth Generation New Radio (5GNR) Distributed Unit (DU) and the BBU is in a 5GNR Centralized Unit (CU).

18. The wireless access node of claim **11** wherein the IAB MT is in a Fifth Generation New Radio (5GNR) Distributed Unit (DU) and the BBU is in the 5GNR DU.

19. The wireless access node of claim **11** wherein the BBU is configured to recover from the fault by rebooting an Internet Protocol (IP) router responsive to the signaling.

20. The wireless access node of claim **11** wherein the BBU is configured to recover from the fault by rebooting an ethernet switch responsive to the signaling.

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